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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

Appln. No.	:	10/677,962	Confirmation No. 9258
Applicant	:	Mark Carter	
Filed	:	10/01/03	
Art Unit	:	1791	
Examiner	:	Michael T. Piery	
Title	:	CATHETER SHAFT HAVING VARIABLE THICKNESS LAYERS AND METHOD OF MAKING	
Docket No.:	:	ACSC-65631 (G1935USD1)	
Customer No.	:	24201	June 9, 2009

Mail Stop Appeal Brief - PATENTS
Commissioner for Patents

APPEAL BRIEF

Dear Sir:

This Appeal Brief is being filed pursuant to the Notice of Appeal that was filed on March 12, 2009. A request for a one month extension of time along with the requisite fees is attached hereto.

INTRODUCTION

The present invention relates to catheters and more particularly pertains to a method of making a catheter having two layers with a co-tapered structure wherein a first layer tapers to a smaller thickness at its distal end while a second layer tapers to a smaller thickness at its proximal end. Previously employed methods for manufacturing such a structure have been unable to provide an adequately short and tailored transition. The present application, U.S. Serial No. 10/677,962 was filed October 1, 2003 and is a divisional of U.S. Serial No. 09/707,681 that was filed November 6, 2000.

I. REAL PARTY IN INTEREST

The real party in interest in this appeal is ABBOTT CARDIOVASCULAR SYSTEMS INC. (formerly Advanced Cardiovascular Systems, Inc., the assignee of record), 3200 Lakeside Drive, Santa Clara, CA 95054, which is a division of Abbott Laboratories, 100 Abbott Park Road, Abbott Par, Illinois 60664-3500. This application was originally assigned by the inventor, MARK CARTER to ADVANCED CARDIOVASCULAR SYSTEMS, INC., by Assignment executed October 11, 2001 and October 21, 2001 respectively, which was recorded by the US Patent Office on October 25, 2001 beginning at Reel 012421, Frame 0441.

II. RELATED APPEALS AND INTERFERENCES

None.

III. STATUS OF CLAIMS

The application was originally filed with 6 method claims (25-30). Claim 31 was added during the course of prosecutions. Claims 25-31 are currently pending, are under final rejection and are being appealed. A clean copy of the claims being appealed is appended as Exhibit 1.

IV. STATUS OF AMENDMENTS

No amendment was filed subsequent to the final Office Action of November 13, 2008.

V. SUMMARY OF THE CLAIMED SUBJECT MATTER

The rejected claims are all directed to a method of manufacturing a "co-tapered" catheter shaft. More particularly, the method provides for the co-extrusion of two different materials by two gear pumps wherein the desired co-tapered configuration is achieved with the simultaneous reversing of one gear pump and the increasing the speed of the second gear pump. Two independent claims are under appeal.

Independent claim 25 is supported in the specification and drawings as follows:

25. A method of making an elongated catheter shaft having at least a first (page 3, line 11; Fig. 2, #26) and second layer (page 3, line 12, Fig. 2, #27), and a co-tapered section (page 3, line 13, Fig. 2, #30) in which the first layer tapers to a smaller wall thickness and the second layer tapers inversely to the taper of the first layer (page 3, lines 10-13) comprising:

a) extruding the first layer from an extruder having a first gear pump (page 19, lines 15-16; Fig. 8, #64) at an output end thereof and co-extruding the second layer with the first layer from a second extruder having a second gear pump (page 19, lines 13-16; Fig. 8, #64) at an output end thereof; and

b) forming the co-tapered section of the shaft by reversing the rotation of the first gear pump (page 20, lines 13-20; Fig. 10) to at least in part form the taper in the first layer and increasing the speed of the second gear pump (page 20, lines 3-6; Fig. 10) from a first speed to a second speed to form the inverse taper in the second layer.

Independent claim 30 is supported in the drawings and specification as follows:

30. A method of making an elongated catheter (page 3, line 6; Fig. 1, #11) shaft having at least a first (page 3, line 11; Fig. 2, #26) and second layer (page 3, line 12; Fig. 2, #27), and a section which is located between ends of the shaft and in which the first layer tapers distally to a smaller wall thickness (page 3, lines 10-13), comprising extruding the first layer from an extruder having a first gear pump (page 19, lines 13-16; Fig. 8, #64) at an output end thereof and co-extruding the second layer with the first layer from a second extruder (page 19, lines 13-16; Fig. 8, #62), and forming the section of the shaft by reversing the rotation of the first gear pump to at least in part form the taper in the first layer (page 20, lines 13-20).

VI. GROUNDS OF REJECTION TO BE REVIEWED ON APPEAL

Pursuant to the Final Office Action dated August 13, 2008, the independent claims were rejected as follows:

GROUND I

Claims 25-27, 29 and 30 were rejected under 35 U.S.C. § 103(a) as obvious over Harris (USPN 5,725,814) in view of Johnson (USPN 3,611,504).

GROUND II

Claim 28 was rejected under 35 U.S.C. § 103(a) obvious over Harris (USPN 5,725,814) in view of Johnson (USPN 3,611,504) and further in view of Tiernan et al (USPN 6,579,484).

GROUND III

Claim 31 was rejected under 35 U.S.C. § 103(a) obvious over Harris (USPN 5,725,814) in view of Johnson (USPN 3,611,504) and further in view of Strum et al (USPN 4,824,618).

VII. ARGUMENT

Each and every claim calls for the method to include a step in which one of two gear pumps is reversed **during** the extrusion process. None of the cited references suggest such a step during the coextrusion of two materials.

GROUND I

The Examiner relies on the Harris reference (Exhibit 2) as teaching the coextrusion of two materials with two gear pumps to form a co-taper by decreasing the rotation of a first gear pump and increasing the speed of the second gear pump. As such, this teaching comprises precisely the prior art that the present invention improves upon as was specifically set forth in the specification at page 2, line 20. The Examiner then relies on the Johnson reference (Exhibit 3) as teaching the reversal of an "extruder" in order to prevent "drool" of the plastic melt and asserts that it would be obvious to combine a method of using two gear pumps to manufacture a catheter shaft having co-tapered layers with a method of preventing "drool" to arrive at the present invention as claimed. This combination however misses the point. The secondary reference is directed to an injection molding process that exclusively employs a feed screw 14, **not a gear pump**. Moreover, the primary reference teaches that the use of gear pumps comprises an improvement over the use of feed screws as feed screws were prone to "drool" and were therefore incapable of relatively quickly changing from the output of one extruder to another or to vary the content so that the extrudate changes gradually in a precisely controlled fashion (col 1, lines 46-59). Although the reference acknowledges that there are, in fact, slight leakages within gear pumps that cause some dependence on output back pressure (col 4, lines 6-8), the reference goes on to teach that "when a gear pump stops, it has the effect equivalent to closing off the output pipe from the extruder (col 4, lines 16-18). Additionally, the reference teaches at col 4, line 3-5 that "the output of a gear pump is proportional to RPM essentially regardless of what happens to the pressure at the output." As such, rather than forming a "co-taper," the reference teaches that stopping one gear pump during the coextrusion of two materials would in fact cause the output of one material to stop completely thereby resulting in an abrupt transition from one material to the other. Moreover, in view of the teaching with regard to the proportionality of RPM to output, one would expect a reversal of one gear pump, i.e. a negative RPM, to result in the removal of material rather than a tapered output. Notwithstanding the teaching of the secondary reference that reversal of a **feed screw** prevents drool, it is respectfully submitted that the reversing one of two gear pumps during the extrusion process unexpectedly results in the desired short and tailored co-taper of a catheter shaft.

GROUND II

The Tiernan reference was cited in the rejection of dependent claim 28 for its disclosure of the length of the taper and as such does not overcome the shortcomings of the Harris and Johnson references with regard to rendering obvious the **method** that is claimed in underlying independent claim 25 as was argued above. As consequence, all claims depending from claim 25 similarly avoid obviousness.

GROUND III

The Strum reference was cited in the rejection of dependent claim 31 for its disclosure of a particular extruder configuration and as such does not overcome the shortcomings of the Harris and Johnson references with regard to rendering obvious the **method** that is claimed in the underlying independent claim 25 as was argued above. As consequence, all claims depending from claim 25 similarly avoid obviousness.

VIII. CLAIMS APPENDIX

See Exhibit 1.

IX. EVIDENCE APPENDIX

None.

X. RELATED PROCEEDINGS APPENDIX

None.

XI. CONCLUSION

For the foregoing reasons, it is submitted that the present invention as claimed is not obvious over any combination of the cited references and that the Examiner's rejections of claims 25-31 were therefore erroneous. Reversal of the rejections of claims 25-31 is therefore respectfully requested.

Respectfully submitted,

FULWIDER PATTON LLP

/Gunther O. Hanke/
Gunther O. Hanke, Reg. No. 32,989

GOH:lm

LIST OF EXHIBITS

EXHIBIT	DESCRIPTION
1	Appealed Claims
2	U.S. Patent No. 5,725,814 - Harris
3	U.S. Patent No. 3,611,504 - Johnson

EXHIBIT 1

CLAIMS

25. A method of making an elongated catheter shaft having at least a first and second layer, and a co-tapered section in which the first layer tapers to a smaller wall thickness and the second layer tapers inversely to the taper of the first layer comprising

a) extruding the first layer from an extruder having a first gear pump at an output end thereof and co-extruding the second layer with the first layer from a second extruder having a second gear pump at an output end thereof; and

b) forming the co-tapered section of the shaft by reversing the rotation of the first gear pump to at least in part form the taper in the first layer and increasing the speed of the second gear pump from a first speed to a second speed to form the inverse taper in the second layer.

26. The method of claim 25 including, after (b), forming a non co-tapered distal section of the shaft adjacent to the co-tapered section by decreasing the speed of the second gear pump from the second speed to a third speed greater than the first speed of the second gear pump and less than the second speed of the second gear pump.

27. The method of claim 25 wherein the shaft has a proximal section and distal section on either end of the co-tapered section having different relative proportions of the first and second layers therein, and including forming the distal section by changing the rotation of the first gear pump from the reversed rotation to a forward rotation and setting the speed of the first gear pump at a second speed less than a first speed of the first gear pump used to form the proximal section.

28. The method of claim 27 wherein the co-tapered section has a length of about 13 cm to about 25 cm, and forming the distal section of the shaft includes decreasing the speed of the second gear pump from the second speed to a third speed.

29. The method of claim 27 wherein forming the co-tapered section of the shaft includes decreasing a speed of the first gear pump from the first speed to a third speed.

30. A method of making an elongated catheter shaft having at least a first and second layer, and a section which is located between ends of the shaft and in which the first layer tapers distally to a smaller wall thickness, comprising extruding the first layer from an extruder having a first gear pump at an output end thereof and co-extruding the second layer with the first layer from a second extruder, and forming the section of the shaft by reversing the rotation of the first gear pump to at least in part form the taper in the first layer.

31. The method of claim 25 wherein the extruder is part of an extrusion apparatus having tip with a tapered section between a uniform diameter section and a die-end section, a die with the die-end section of the tip therein from a polymer-receiving end of the die to an opposite output end of the die to form the catheter shaft as a tubular extrudate, and an extended flow divider at a location which receives a first layer polymeric material and a second layer polymeric material from the gear pumps, and which separates the flow of the first layer polymeric material from the second layer polymeric material upstream of the die, and which extends to an end of the tapered section of the tip at a junction between the tapered section and the die-end section of the tip, and the method includes separating the first and second layer polymeric materials with the extended flow divider until the polymeric materials are at the polymer-receiving end of the die.

US005725814A

United States Patent [19]

Harris

[11] **Patent Number: 5,725,814**

[45] **Date of Patent: Mar. 10, 1998**

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[54] **EXTRUSION OF AN ARTICLE OF VARYING CONTENT**

[75] Inventor: **Holton E. Harris**, Westport, Conn.

[73] Assignee: **Harrel, Inc.**, Norwalk, Conn.

[21] Appl. No.: **477,437**

[22] Filed: **Jun. 7, 1995**

[51] **Int. Cl.**^{6} **B29C 47/92**

[52] **U.S. Cl.** **264/40.3**; 264/40.7; 264/209.4; 264/211.13; 264/167; 264/171.26

[58] **Field of Search** 264/40.3, 40.7, 264/209.1, 209.4, 167, 211.23, 401, 171.1, 171.26; 45/131.1, 133.1, 140, 141, 145, 205, 209, 462

[56] **References Cited**

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"The Geartruder by Harrel," Harrel, Incorporated. Undated.

"Melt Pump Systems for Extruders by Harrel," Harrel, Incorporated. Undated.

Harrel Incorporated—Four Extruder, Four Gear Pump Sheet Co-extrusion Installation. 1982, per attached photograph.

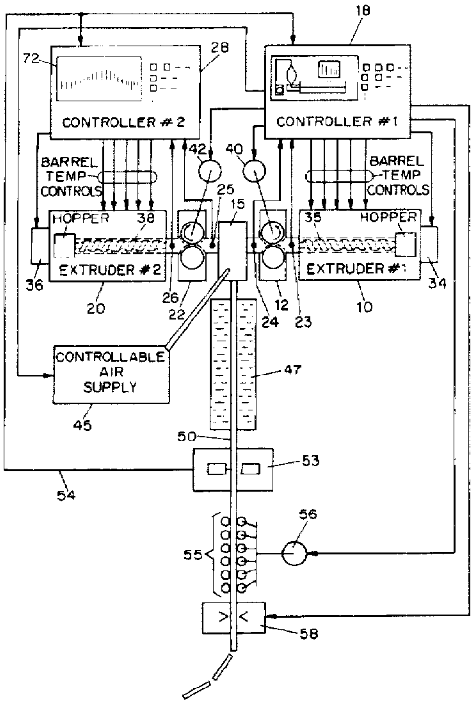
Primary Examiner—Khanh P. Nguyen

Attorney, Agent, or Firm—Brumbaugh, Graves, Donohue & Raymond

[57] **ABSTRACT**

A coextrusion system employs two or more extruders, each with a gear pump at its output connected to a coextrusion die. Different materials are extruded by each extruder. Varying the speed of one or both gear pumps varies the content of the extrudate. The gear pumps permit precise variation of the relative content of the materials extruded by the several extruders lengthwise along the extrudate. A display of a cross sectional dimension of the extrudate along a length of the extrudate permits observation of the lag that occurs between alteration of gear pump speed (or air pressure in the case of tubular or blown sheet extrudates) and the resultant change in dimension, so that a speed correction can be made at the appropriate time to compensate for differing shrinkage and stretching characteristics between the several extruded materials.

31 Claims, 4 Drawing Sheets



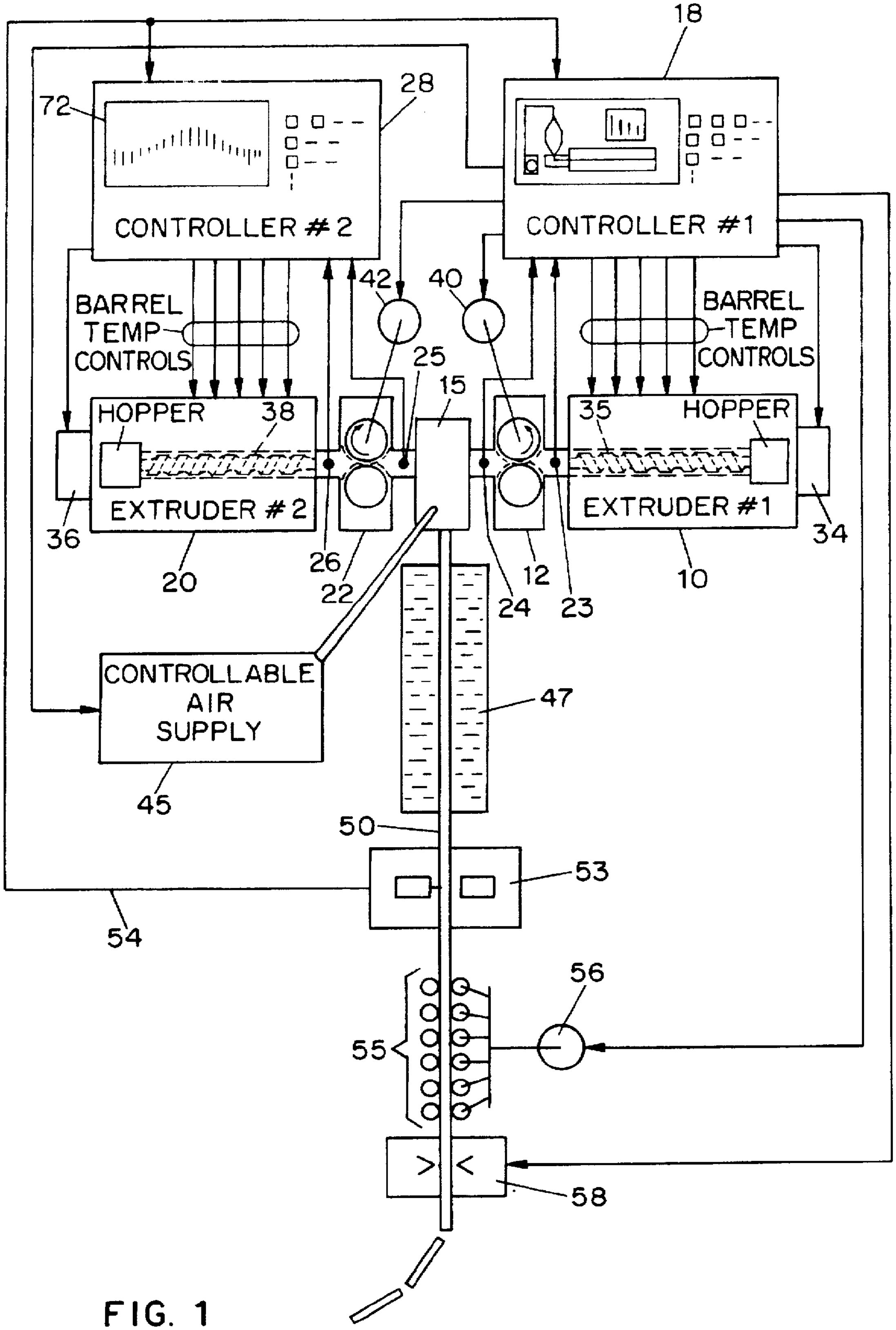

CONTROLLER #2
CONTROLLER #1
BARREL TEMP CONTROLS
BARREL TEMP CONTROLS
HOPPER
HOPPER
EXTRUDER #2
EXTRUDER #1
CONTROLLABLE AIR SUPPLY

FIG. 1

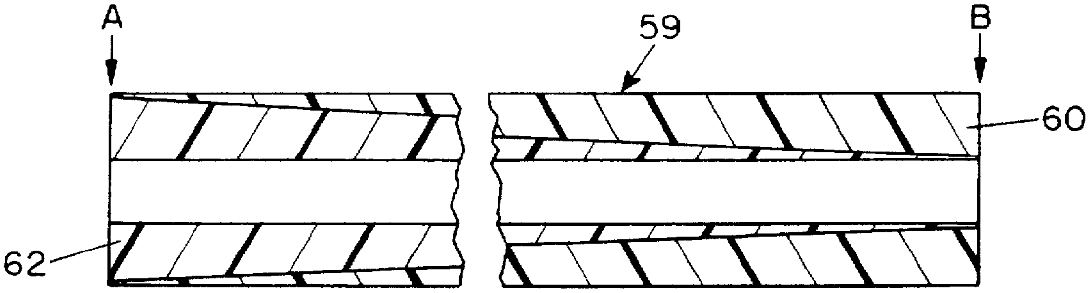


FIG. 2

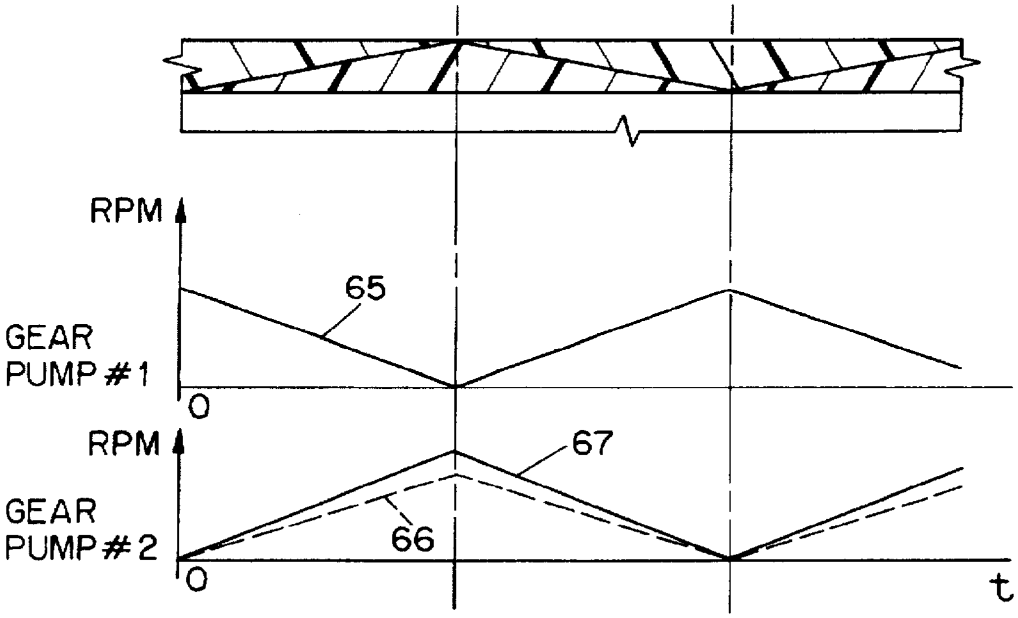
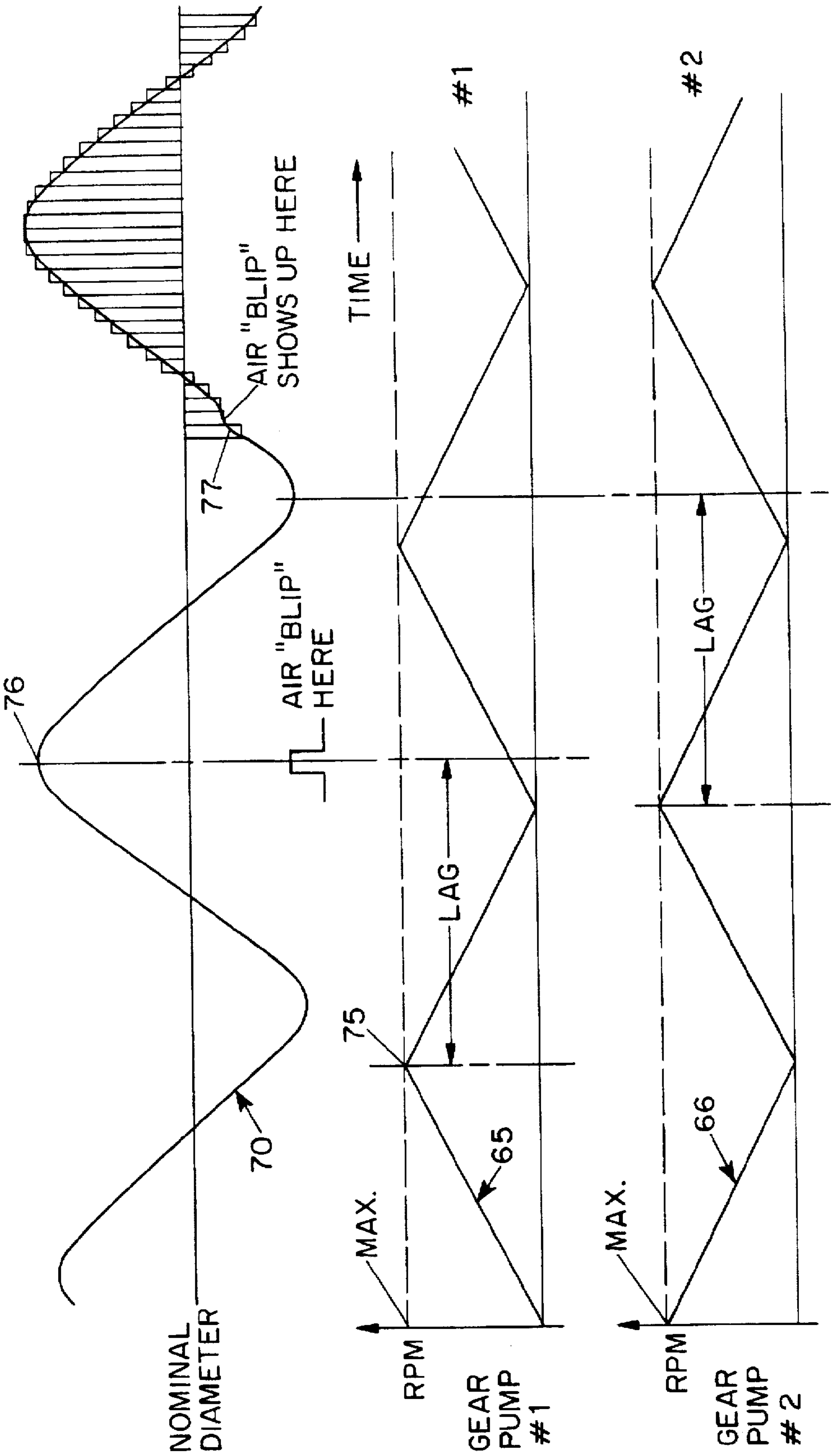


FIG. 3


NOMINAL DIAMETER
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76
AIR "BLIP" HERE
77
AIR "BLIP" SHOWS UP HERE
TIME →
RPM
GEAR PUMP #1
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65
75
LAG
#1
RPM
GEAR PUMP #2
MAX.
66
LAG
#2

FIG. 4

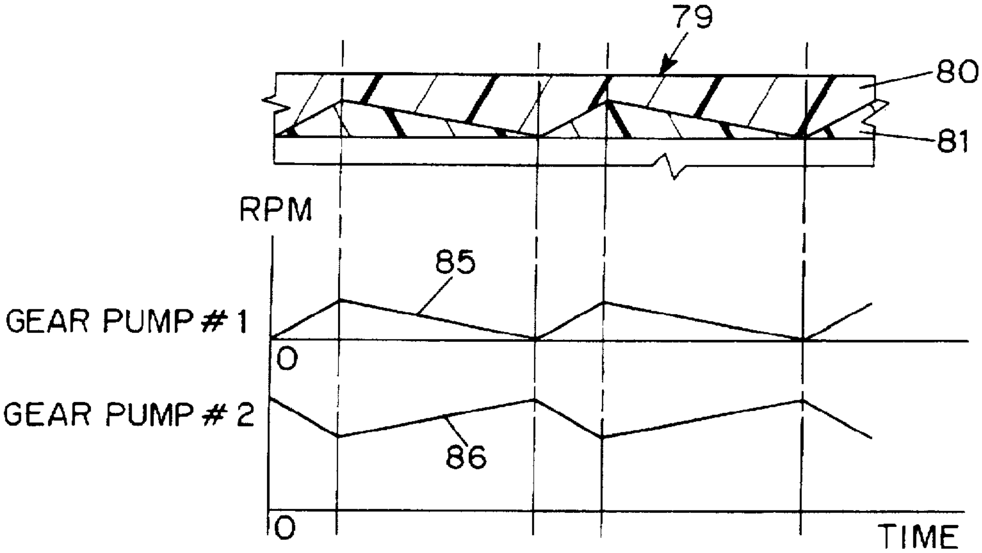


FIG. 5

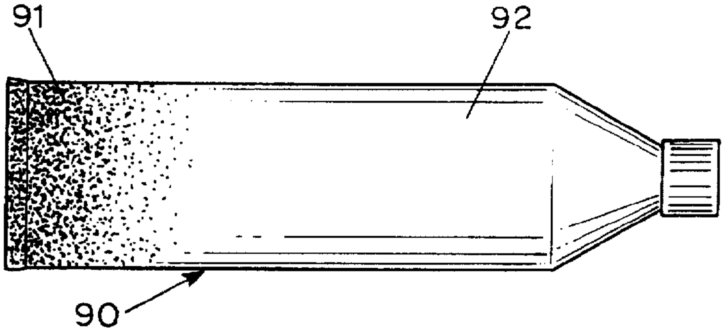


FIG. 6

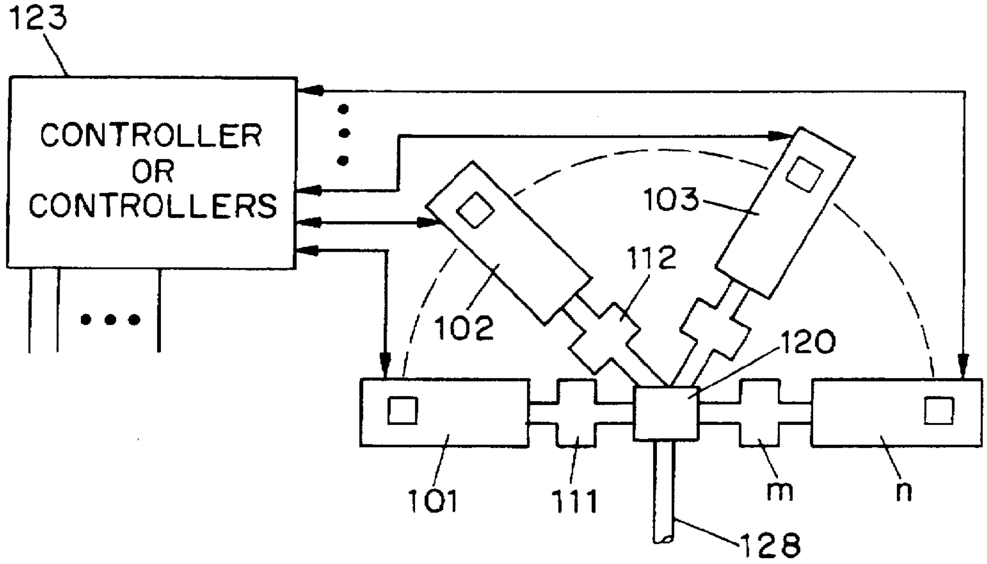


FIG. 7

EXTRUSION OF AN ARTICLE OF VARYING CONTENT

SPECIFICATION

BACKGROUND OF THE INVENTION

This invention relates to methods and apparatus for coextrusion of products formed of at least two differing materials, and more particularly to methods and apparatus employing two or more extruders, each with a gear pump, to coextrude an extrudate that varies along its length in the relative proportion of differing constituent materials.

Tubes, pipe, sheet, film, profiles and other extruded products made of plastic, for example, have different characteristics that depend on the particular plastic being used. One plastic will be very flexible, while another will be very stiff. One may be transparent, while another is opaque, etc. For many applications it would be desirable to make an extruded product that is a coextrusion of two or more materials that changes from one material to another abruptly or gradually or that varies along its length in the relative content of the two or more constituent materials.

Coextrusion is a process by which two or more extruders are connected to a single, coextrusion die. The individual extruders feed to the die differing materials, by differing materials is meant not just different types of materials such as nylon and polyurethane, but materials of differing characteristics or qualities, such as color, opacity or density. The extrudate from the coextrusion die is, then, a multiple material extrudate. An example of a coextruded product is a tube extruded by a pair of extruders feeding a coextrusion die that directs a first material to the outside of the extruded tube and directs a second material to the inside of the tube. The result is a coaxial, two-layer, tubular extrusion.

Extruders have been connected directly to coextrusion dies, but with less than optimum results. A plastic extruder, for example, is a device that has a large barrel with a large motor driven screw in it. Plastic pellets are put into a hopper end. A molten plastic stream comes out the other end. Since the screw is an inefficient pump, it generates much friction and heat as it turns. Enough energy is converted from the mechanical energy of the screw into heat energy to melt the plastic. The plastic stream eventually gets forced through the die, forming it into garden hose, medical catheters, tubing, sheet, etc.

An extruder screw, however, is not a positive displacement pump. The amount of plastic which comes out the exit end is not exactly proportional to the speed of the screw. The throughput varies with the viscosity of the plastic, the pressure at the die and other variables.

If one varies the speeds of the extruders of a coextrusion system, one theoretically varies the amount of each of the materials in the extrudate. However, with extruders this variation cannot be precisely controlled and it is virtually impossible to change relatively quickly from one material to the other, or to vary the content so that the extrudate changes gradually in a precisely controlled fashion from one material to another. One reason for this is that the extruder is subject to considerable "drool." If an extruder screw is stopped, there is still a great deal of plastic that can come out of the grooves of the screw. Consequently, if extruders are used for the above-mentioned scheme for varying the material content along the length of the extrudate, there are several problems:

a. The inertia of the screw, motor, gear box system in an extruder is high. It is consequently very difficult to control the speed accurately or quickly.

b. The output of an extruder is not linear with speed, so it is not possible to predict what the total output from two or more extruders will be.

c. The drool from the extruders will distort the control of the percentages of each material.

d. Since the extruders react on each other through the back pressure created in the die, the output of each extruder is affected not only by what happens in that extruder, but also by what happens in all of the others. Hence, if one attempts to deliver more material from one extruder by increasing its speed, the pressure at the die increases, not just for that extruder, but for all others, reducing their output.

One way to change from one extrudate material to another is the use of a valve to effect the change. The valve allows one material to go into the die while the other is diverted and discarded in the scrap bin. The two flows can then be reversed and an extrudate varying in content results. Obviously that system is extremely wasteful.

Even if control of the amount of constituent materials is attained, these materials may have different characteristics that cause the dimensions of the extrudate to depart from those being sought. Differing amounts of shrinkage during cooling, and differing amounts of the stretch that occurs between the die and the extruder's puller can cause cross sectional dimension variations as the material content in the extruder changes.

It will thus be apparent that there exists a need for an extrusion system capable of extruding two or more materials with repeatability, stability and predictability, capable of abrupt or gradual changeover of materials and of accurate dimensional control as well as content control.

BRIEF SUMMARY OF THE INVENTION

In accordance with this invention, by the use of gear pumps, the above shortcomings are avoided in a coextrusion method and system that varies extrudate material content. Two or more extruders are employed in combination with a coextrusion die and a gear pump is interposed between each extruder and the die. The amount of each material being delivered to the die is varied by controlling the speed of each gear pump.

A gear pump is formed from two counterrotating gears which are tightly meshed. The gear pump is used on the end of the extruder and acts as a metering pump to meter out a precisely measured amount of material. The gear pump can be thought of as a group of measuring cups on a wheel. The measuring cup—in this case the pocket between the teeth of the pump is filled with material such as plastic melt at the input. It travels around the pump, getting levelled as it does so, so that the amount carried from input to output is precisely one tooth-full. At the output the gears mesh very closely, so the material cannot get back to the input, and so it exits.

This type of pump is a positive displacement pump. The amount which exits is precisely proportional to the RPM of the pump to a very close tolerance, and the pump is relatively insensitive to such factors as viscosity, pressure, etc. This gives the gear pump greater repeatability, stability, and predictability than the extruder. When an extruder stops there is still an open channel all the way back to the hopper, and material drools out. When a gear pump stops, on the other hand, there is just one tooth-full of melt from the top gear and one from the bottom that is open. The gear pump is a much smaller device. It has much less inertia. Consequently, its speed can be changed a great deal faster than that of an extruder. The upstream material is closed off firmly by the tight fit between the teeth of the gears of a gear pump and the housing of the pump. Gear pump speed control will thus accurately control the rate of delivery of material to the die. By using gear pumps between the extruders and the die of a coextrusion system, the amount of each constituent material at each location along the extrudate can be precisely controlled.

In a two extruder system, for example, the extrudate can be changed from one material to another by increasing the speed of one pump from completely stopped, while slowing the speed of the other pump to a stop. If the extrudate is to be made without dimensional change, in theory the sum of the speeds of the gear pumps should remain constant. However, different materials shrink differently with changes in temperature and consequently the cross sectional dimensions of an extrusion will change as it changes from one material to another. Compensation for this can be made by an incremental change in one of the gear pump speeds so as to either deliver more of the plastic that exhibits the higher shrinkage or to deliver less of the plastic that shrinks less.

Similarly, where stretch between the die and a puller varies from one material to another, tending to alter a cross sectional dimension, compensation can be effected in a system employing gear pumps by changing pump speed slightly, or in the case of a tube or blown film by correcting not only a pump speed, but air injected at the die.

Although this sounds relatively straightforward, in practice a change in speed of one of the gear pumps has an effect on the extrudate only after a considerable lag. That is to say, the increase in speed of one gear pump will produce a higher content of that gear pump's material only after the material intermediate the gear pumps and the die outlet has been forced through the die. In an embodiment of this invention, a laser gauge downstream of the die was used to detect a variation in dimension. A sudden temporary gear speed change will show up on a monitor that displays cross sectional dimension. The lag, in terms either of time or length along the extrudate, is determined and the shrinkage or stretch compensating correction is made in advance of the extrusion of that portion of the extrudate requiring the correction. The time or distance in advance that the correction is made is the time or distance of the measured lag. Similarly, where air is used to control outside diameter a "blip" or sudden pulse of air is introduced and the line lag to the laser gauge is noted, whereupon a correcting air input can be subsequently made at the correct location.

A coextrusion die that can make tubing with two layers is well-known in the industry. The thickness of each of the layers is proportional to the amount of plastic which goes into each of the two inputs of the die. Using this with two extruders fitted with gear pumps, catheters for use in brain surgery were made that were extremely flexible at the forward tip, but stiff in the rear portion of the catheter, enabling manipulation during entry into the body. In this case the extrudate was changed from nylon to polyurethane and back again. It was severed at the midpoint of each location of entirely one plastic. The nylon formed the rear portion of the catheters and the polyurethane the leading tip. The transition took place in about 40 inches.

Another application of the invention is the extrusion of a product that gradually changes from one color to another, or from opaque to transparent, by virtue of changing from one material to another as described. Other applications of extrusions of two or more materials and varying characteristics from one location to another will be recognized.

Unlike coextrusion systems using extruders without gear pumps as alluded to above, pressure at the die is not a factor in systems according to the present invention. The output of the gear pump is proportional to RPM essentially regardless of what happens to the pressure at the output.

There are, in fact, slight leakages within a gear pump that cause some dependence of output on back pressure, but it is very much less than in an extruder. Further, systems of this invention control not just the input pressure at the pump, but also the differential pressure across the pump. This greatly reduces the effect of back pressure. Systems with gear pumps almost always achieve volume stabilities of 0.1% or better, even in the presence of varying back pressure.

In the case where the extrudate is changed abruptly from one material to another, the problem of pressure in the extruder is made more severe. When the gear pump stops, it has the effect equivalent to closing off the output pipe from the extruder. The blockage is essentially complete, and as already noted, it is difficult to stop an extruder abruptly because of inertia.

The usual problem in extruder screw design is to minimize leakage flow in the screw. In other words, normally one wants as nearly as possible to clear out the plastic in the flights every time an extruder screw rotates. In normal screw design the problem is to do this in the face of the fact that it takes a considerable pressure—typically 2000 PSI or more—to force the plastic through the die. This pressure is generated in a normal screw by a decrease in the depth of the screw, and in an extruder the downstream portion of the screw—the metering section—has a much shallower depth than the preceding sections. The shallower depth in the downstream end allows the screw to generate more pressure.

In a system according to this invention, for abrupt material change, because there is a gear pump at the output of each extruder, one does not need to generate the pressure in the extruder screw to force the plastic through the die. The gear pump does that. Only enough pressure is needed to force the polymer through the extruder's screens and to ensure, as noted above, that the teeth of the gears in the gear pump are filled. This only takes pressure typically on the order of 300 psi. The gear pump generates the rest of the pressure to force the polymer through the die.

For this application, therefore, one can use a screw that is deliberately designed to be a poor pressure generator—for example by having the metering section with much deeper flights than normal. This would be unsuitable for use without a gear pump, but is very tolerant of increases in back pressure when the gear pump stops. Nevertheless, the extruder is not kept going any more than needed, because that would generate extra heat in the polymer. However, the gear pump can be stopped abruptly, and the extruder can be brought to a stop more gradually without the problem of extreme pressure build-up. Control of such a system is accomplished by a feedback control controlling the RPM of the extruder based on the differential pressure across the pump. This is known for example, from this inventor's U.S. Pat. No. 4,209,476, incorporated herein by reference. Because it is the gear pump that precisely controls the delivery of material to the die, the extruder speed need not be controlled accurately.

The process is applicable to any number of extruded products such as profile, sheet, blown film, tubes, pipe, etc. Although the catheter referred to above as a specific embodiment varied from 100% of one polymer from one of the gear pumps to 100% of the other polymer from the other of the gear pumps, the technique is not limited to that configuration. Other ratios and schedules of variations are apparent. Also, although it is described herein how the cross sectional dimension of an extrudate may be maintained constant by accounting for variations in shrinkage and stretch, it is not necessary that the extrudate be maintained constant in cross sectional dimension if variation in that dimension is desired.

The lag between cause and affect, as it were, can be determined and compensated for. A programmable, microprocessor-based controller like the assignee's DIGIPANEL has a display capable of indicating in bar graphs the thickness of extrudate measured at a gauge downstream of the die and over a length of extrudate exceeding more than a complete cycle or even multiple cycles in the variations in plastic content. In the coextrusion of a plastic tube, first, it is noted when one pump is at its maximum speed. Second, the laser gauge display is observed to determine time lag between pump speed changes and changes in diameter at the laser gauge. This is the lag due to both plastic in the system between the pump and the die and the distance from the die to the laser gauge. Third, a "blip" of air change is introduced into the tube at the die and a time lag before this appears at the laser gauge is determined. Compensation for variations in extrudate dimensions due either to shrinkage or stretch can now be begun by introducing at the correct location to produce at the affected extrudate location appropriate corrective action in either speed or air pressure or both, and of course, when the extrudate varies in its content in a desired manner such as gradual increase from one plastic to another, then a program of changes to compensate for the varying dimensional effects is introduced via the controller.

The foregoing corrective action can be obtained by the operator making the above-noted observations and manually adjusting speeds and/or air pressure as indicated, or the controller program can be modified to automatically make the compensatory changes.

The assignee Harrel, Incorporated's TUBETROL control loop, operates on a principle like that described in the inventor's above-mentioned U.S. Pat. No. 4,209,476. It controls the inside and outside diameters of extruded tubing of a single material. The outside diameter is controlled by the air pressure introduced into the tube at the die. The inside diameter is a function of the relative speeds of the gear pumps and the puller. Control of the puller speed then can control the inside diameter. When it is found that the outside diameter is too small the internal air pressure is increased and the system waits until the change appears at the laser gauge. If the correction is not sufficient, it increases the air more, etc. The same time lag is present as in the coextrusion process, but because there is no change in composition affecting diameters at a particular point along the tube material variation cycle, it does not matter where along the extrudate the change is made.

Hence, an automatic closed loop control has to do just what has been described above to compensate for dimensional changes in a coextruded extrudate of changing composition. The cross sectional dimension of the entire cycle of tubing, or other extrudate, would be recorded in the memory banks of the system. In the case of a tube this would be the OD and the ID. If part of the tubing is too small, for example, instead of just gradually increasing the air, the system puts in a momentary increase in the air pressure, a "blip," large enough to have a clearly recognizable effect, but only lasting for a short period. It then monitors the profile continually for the next cycle or so and compares the value at each point with the values stored in its memory banks. There will be one point which is measurably larger than it was previously. The time lag between the "blip" in the air that was inserted in the die and the time the corresponding "blip" in diameter showed up on the laser gauge is now the raw delay. This delay can be used to correct the normal TUBETROL routine so that it takes account of the lag. Likewise, taking into account the appropriate lag the gear pump speeds can be controlled to control material-dependent changes in thickness.

The above and further objects and advantages of the invention will be better understood with respect to the following detailed description preferred embodiments considered in combination with the several figures of the accompanying drawings.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic block diagram of a system for extruding products of two materials of varying content.

FIG. 2 is a fragmentary cross sectional drawing of an extrusion varying in content from one material to another along its length.

FIG. 3 is a graphical illustration of gear pump speed versus time for the two gear pumps of a system like that of FIG. 1 and producing an extrudate varying in content from one material to another along its length.

FIG. 4 is a graphical illustration that plots diameter variation, gear pump and the speed of two gear pumps against time for an extrudate varying in content but not changing entirely from one material to another along its length.

FIG. 5 is a graphical illustration like FIG. 2 for an extrudate varying in its constituent content along its length, but without changing entirely from one material to another.

FIG. 6 is a side elevation of a tube of product made in accordance with this invention, the tube varying in a visual characteristic along its length.

FIG. 7 is a block diagram indicating the arrangement of three or more extruders and gear pumps in a coextrusion process according to the invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

In FIG. 1, a first extruder **10** is connected with a gear pump **12** and a second extruder **20** is connected with a gear pump **22**. A coextrusion die **15** receives the output of the two gear pumps. A first controller **18**, which may be a Harrel, Incorporated CP-871 DIGIPANEL extrusion controller, controls, in a manner known in the art, the temperature along the barrel of extruder **10** and controls the speed of a screw drive motor **34** that drives a screw **35** of the extruder **10**. A second controller **28** controls the temperature of the second extruder **20** at multiple zones along the extruder barrel, again as known, and controls the screw drive motor **36** that drives the screw **38** of the second extruder. The gear pump **12** is driven by a servo-motor **40** controlled by the controller **18**, and likewise the gear pump **22** is driven by a servo-motor **42** also controlled by the controller **18**, again as shown in FIG. 1.

A controllable air supply **45** introduces compressed air to the die **15** under control of the first controller **18**. A water trough **47** receives an extrudate **50** as it emerges from the die **15** and before it passes to a laser gauge **53**. The laser gauge passes a cross sectional dimension measurement of the extrudate to the two controllers **18** and **28** via a line **54**. A conventional puller **55** pulls the extrudate through the water trough **47** and past the laser gauge **53**. A drive motor **56** of the puller **55** is under the control of the first controller **18**. A cutter **58** that severs the extrudate **50** into desired lengths at desired locations is also controlled by the controller **18**. The combination extruder and gear pump **10** and **12**, and **20** and **22**, may be the combination of such offered by the assignee Harrel, Incorporated under the trademark GEARTRUDER.

The rate of delivery of materials, or "melt," by the gear pumps **12** and **22** to the coextrusion die **15** is directly proportional to the speed at which the pumps are driven by their servo-motors **40** and **42** under the control of the first controller **18**. Variation of the speed of either gear pump will vary the content in the extrudate **50** of the material being delivered by that pump. Since the rate of delivery of material is independent of extruder speed, extruder speed control is based upon the pressures at the input and output of the gear pump as described in the aforesaid patent. These pressures are detected by detectors at **23**, **24**, **25** and **26** and conveyed as signals to the controllers **18** and **28**.

In FIG. **2**, a tubular extrusion **59** has two coextruded plastic layers **60** and **62**. The inside and outside diameters of the extrusion remain substantial constant along its length. The content of the two constituent plastics varies from a location A where the extrusion is entirely the plastic of layer **62** to a location B where the extrusion is entirely of the plastic of layer **60**. Such an extrusion is produced with the system illustrated in FIG. **1** by ramping-up the gear pump **12** while ramping-down the gear pump **22** and vice versa. This alternate ramping-up and ramping-down of the two gear pumps is graphically shown in FIG. **3** in juxtaposition to a corresponding length of the extrusion which is partially shown in cross section above the plot of gear pump speed versus time.

To provide increased pressure from an extruder, ordinarily an extruder screw will have deeper flights at the input or feed zone and shallower flights at the output or metering zone. This compression ratio between the zones will ordinarily be in the range of 2 to 1 to as much as 4 to 1 or more. However, in the present system it may be 2 to 1 or less. This is possible because the gear pumps, and not the extruders, are used to deliver melt to the die. The deeper screw flights in the metering zone also allow a gear pump to stop abruptly while the extruder comes to a stop more slowly, and there is no resultant excessive build-up of pressure at the input to the gear pump.

If the characteristics, such as shrinkage and stretching, that effect the cross sectional dimension of the product are the same for the two materials **60** and **62**, then the gradual change-over from one material to the other with no change in the inside and outside diameters can be effected by gear pump speed variations as illustrated by solid line **65** and the broken line **66** of FIG. **3**, which speeds change at exactly the same rates, but entirely out of phase such that the sum of the two speeds is always a constant. This of course assumes that the gear pumps 1 and 2 are of identical size, whereas if they vary in size a compensating speed correction is necessary in one or both to assure that their combined rate of delivery is constant.

If the cross sectional area affecting characteristics such as shrinkage or stretching differ between the two materials **60** and **62**, then to maintain a constant inside and outside diameter it is necessary to make a compensatory change in the speed of one of the pumps. The FIG. 3 illustration assumes that the material delivered to the coextrusion die by the gear pump 2 shrinks more as it cools during its travel from the die through the water trough to the laser gauge and the puller. A compensatory incremental change in the speed of the gear pump 2 brings its speed to the speed illustrated by the line **67** in FIG. **3**. Of course, the compensatory change in speed will need to vary as the pump **2** contributes more or less material to the extruded product, again as shown.

Although appearing straight-forward, a correction of the kind illustrated in FIG. **3** is not so easily accomplished. FIG. **3** aligns a cross section of extruded product with the plots of gear pump speed, but no such alignment exists in an extrusion system such as that of FIG. **1**. Because of the inventory of material between the gear pump and the die outlet, a lag exists between an increase in speed of a gear pump and a noticeable increase in the material from that pump in the extrudate. Because of the travel distance from the die to the laser gauge, a further lag exists between the emergence of the change effected by a gear pump speed change and its detection at the laser gauge **53**.

Similarly, a change in the air pressure supplied to the die **15** from the controllable air supply **45** does not appear at the laser gauge **53** until after the second period of time or second lag which is the time required for an extrudate location to move from the die to the gauge.

FIG. **4** illustrates the relationship between the gear pump speed changes and the extrudate diameter for an extrudate like that illustrated at FIG. **2**. Again the plot of gear pump speed versus time for the first gear pump is designated **65** and the plot of uncorrected speed for the second gear pump is designated **66**. Above those plots appears a plot **70** of outside diameters measured by the laser gauge **53** and displayed on a display **72** of the second controller **28** illustrated in FIG. **1**.

When one of the two extruders **10** and **20** is providing a soft material such as a soft polyurethane while the remaining extruder is supplying a harder material such as nylon **11**, if the air pressure introduced by the supply **45** inside the extruded tube and a ratio of the puller **55** speed to the gear speeds are maintained the same for both polymers, the tubing dimensions will vary as the tube varies from one composition to the other. The stretch imparted to the tube by the rolls of the puller **55** differs from the one plastic to the other. Moreover, the air that is introduced into the extruded tube to establish the outside diameter "blows-up" the tube a varying amount as the material content of the tube varies." In the TUBETROL process of the assignee of this invention, both the inside and outside diameter of tubing is controlled as the tubing is extruded. A laser gauge like the gauge **53** is used to monitor the outside diameter of the tube and by feedback the controller varies the air pressure inside the tube to restore the outside diameter to its proper value if a departure is observed. The inside diameter is controlled by varying the ratio of the speed of the puller to the speed of the gear pump.

When a gear pump is used, the output volume is proportional to the speed of the pump to very close tolerances. The volume per hour of the gear pump-equipped extruder therefor is determined by the speed of the pump. The length per unit time of extrudate produced is proportional to the speed of the puller. Maintaining the ratio of the pump speed to the puller speed constant maintains the ratio:

$$\frac{\text{VOLUME/HR}}{\text{FT/HR}}$$

In this ratio, the time cancels out, leaving: VOLUME/FT. The volume per foot, however, is the cross sectional area. Consequently,.controlling the volume per foot and the outside diameter clearly controls the inside diameter too.

Using a gear pump, one knows the volume of a given length of tube because it is dependent on the speed of the pump, which one knows. And using a laser gauge the outside diameter is known. Consequently, such a system can be calibrated in ID, and the ID can be controlled even if it cannot be measured directly. This system operates well for tubes of a single constituent. However, where two materials are employed in a coextrusion process to alter the content of the extrudate along the length thereof, and where the two materials have differing characteristics, correction in this manner is complicated by the lag that occurs between the corrective action and the occurrence of the correction in the extrudate.

The above-referenced DIGIPANEL controller of Harrel, Incorporated can display inside and outside diameters as a series of bar graphs as indicated towards the right end of plot **70** of outside diameters in FIG. **4**. These have been simplified into a single curve throughout the remainder of the plot. The maximum speed of the first gear pump **12**, which is point **75** on plot **65** in FIG. **4** corresponds to the maximum diameter point **76** on the plot **70** of diameters measured by the laser gauge **53**. The lag is shown to be greater than the length of one complete change-over of material in the extrudate, and it may be much longer than this for an extrudate of very small cross section.

With several factors possibly acting to vary the dimension measure by the laser gauge and without knowing what point on a given display corresponds to what point in the varying speeds of the pumps, it is not immediately apparent how to correct undesired dimensional changes.

A brief pulse of increased air-pressure introduced at a point corresponding to point **76** in the extrusion does not show up in the display until point **77**. Consequently, it becomes apparent that it is not easy to alter gear pump speed to compensate for changes in inside diameter occasioned by changes in material content in the extrusion. Likewise, it is not so simple to change the air pressure to compensate for observed changes in an outside diameter.

Such compensation can be accomplished, however, after determining the lag between cause and affect, so to speak. By noting the lag between the introduction of the air "blip" at a point corresponding to point **76** and the appearance in the display of its affect at point **77**, the lag between the die and the laser gauge is determined. As will be appreciated, this lag represents the movement of the extrudate from the point of introduction of the air blip at the die to the location of the laser gauge. It is somewhat shorter than the lag between a gear pump speed change and its appearance at the laser gauge. The latter includes the time lapse between the speed increase and the effect on the extrudate at the die plus the time it takes for this effect to move from the die to the laser gauge as pointed out above. Likewise, by noting the delay between a gear pump speed change and its effect on the displayed diameters it is possible to determine when gear pump speed should be changed to cause a correction in the appropriate point along the extrudate.

The system can be used, in addition, to control the thickness of the tube of different materials without changing the proportional content. In this case, the thickness of the wall vs the distance along the tube is calculated and displayed. Then when variations in thickness are noted, a correction term is inserted into the speed control of the puller to increase or decrease the thickness, as required. As a practical matter, it should be noted that when the RPM of the puller is changed, it is almost always necessary to change the air too. In other words, it becomes necessary to correct both the air and the puller.

An example of an actual run of the system of FIG. **1** to make the above-mentioned catheter product was as follows:

	Extruder #1 & Gear Pump	Extruder #2 & Gear Pump
Barrel Zone #1	360° F.	390° F.
Barrel Zone #2	370	410
Barrel Zone #3	370	420
Head Zone	380	440
Zone 5 not used		
Adapter Zone 6	390	430
Gear pump Zone 7	390	420
Adapter Zone 8	390	420
Zone 9 not used		
Die Zone 10	430	

The melt temperature out of the first gear pump was 390° and out of the second was 433°.

Head Pressure was 1170 psi.

Inlet pressure to pump was 960 psi.

Discharge pressure from pump was 680 psi.

The air pressure required was very low at all times—below 10 inches of water.

Extruder **#1** was running polyurethane and extruder **#2** was running Nylon **11**.

When the system was run without any correction, making nominally 41 mil tubing, the difference between the diameters of the nylon and the urethane was about 13 mils. With a half hour or so of adjustment by the operator as described, this was reduced to less than 1 mil difference.

Although an extrudate changing entirely from one material to another has been discussed, it is clear that a coextrusion wherein the proportions of the two constituent materials change less than entirely along the length of the extrudate is quite possible using the system of FIG. **1**. FIG. **5** shows a partial cross section of a tube **79** in juxtaposition with a plot of the speeds of the first and second gear pumps such as might be used to produce such an extrusion. The extrusion **79** is of two plastics **80** and **81**. The plot **85** of the speed of the first gear pump versus time corresponds to the delivery of the plastic **81** to the die and the plot **86** of the second gear pump corresponds to the delivery of the plastic **80** to the die. In this case a similarity of shrinkage, stretching and any other dimension-affecting characteristics is assumed, so no compensatory change in speed is illustrated, but in the event that these characteristics differ from plastic **81** to plastic **80**, then corrective action such as that described above would be called for.

FIG. **6** illustrates a squeeze tube **90**, such as may package any of a wide variety of consumer products. The central body portion of the tube has been formed using the coextrusion process described above. Here, the two materials, typically plastics, differ in color or opacity, and thus shows up in the product as seen in the darker appearance in area **91** of the tube as compared to area **92**. If the difference in appearance is a change in opacity, then at the end **91** of the tube the content is not visible through the tube, and in the area **92** the interior product is visible.

There are applications in which a change in cross sectional dimension of an extruded product is called for. With the control provided by the system described above, a coextrusion process can be used to make a product changing in cross sectional dimension, such as a tube, that increases and decreases in outside diameter and/or wall thickness. Control of the puller speed to gear pump speed relationship (i.e., by increasing or decreasing puller speed for example) and control of air pressure permits variation of diameter and/or thickness within the limitations of the coextrusion die.

In FIG. **7**, three or more extruders **101**, **102** . . . n are connected with three or more gear pumps **111**, **112** . . . m, all of which are connected to a die **120**. A controller (or controllers) **123** controls the extruders and pumps as well as any puller, cutter, gauges, etc. (all unshown in FIG. 7). An extrudate **128** that may be of three or more materials is thus formed and may be varied in content as desired. Moreover, it is not necessary to run all extruders, and consequently, extrudates of one, two, or more materials can be extruded.

From the above, it will be seen that an improved coextrusion process and system has been provided. The above-described preferred embodiments of the invention are exemplary only. The spirit and scope of the invention should not be understood to be limited by these. Rather, the scope of the invention is set forth in the appended claims.

I claim:

1. A process of extruding an extrudate with different materials, the proportions of which vary along the length of the extrudate, including:

providing a first extruder having a first gear pump at an output end thereof,

providing at least one further extruder having a second gear pump at an output end thereof,

providing a die,

directing material of a first kind from the first extruder through the first gear pump to the die,

directing material of a second kind from the at least one further extruder through the second gear pump to the die,

providing a controller operatively connected to the first and second gear pumps, and

with the controller, varying the speed of at least one of the first and second gear pumps relative to the remaining of the first and second gear pumps to vary the relative content of the first and second kinds of materials in the extrudate.

2. The process according to claim **1** or further including varying with the controller the speed of both of the first and second gear pumps to vary the content of both of the first and second kinds of materials in the extrudate.

3. The process according to claim **1** further including adjusting with the controller the speed of at least one of the first and second gear pumps to control cross-sectional area in the extrudate.

4. The process according to claim **3** wherein adjusting the speed to control cross-sectional area includes adjusting with the controller the speed of at least one of the first and second gear pumps to compensate for differing dimension-affecting characteristics of the two kinds of materials which affect a cross-sectional dimension of the extrudate.

5. The process according to claim **4** wherein adjusting the speed of at least one of the first and second gear pumps to compensate for differing dimension-affecting characteristics includes providing a compensatory incremental speed increase to the gear pump that pumps one of the different kinds of materials having a greater shrinkage as it cools.

6. The process according to claim **4** wherein adjusting the speed of at least one of the first and second gear pumps to compensate for differing dimension-affecting characteristics includes providing a compensatory incremental speed decrease to the gear pump that pumps one of the different kinds of material having a lower shrinkage as it cools.

7. The process according to claim **4** further comprising determining a lag between the speed adjustment of one of the gear pumps and the resultant variation in content in the extrudate of the material from that pump, and then making the shrinkage compensating speed change at a time that precedes by the determined lag the emergence from the die of that location on the extrudate where the compensatory change is to occur.

8. The process according to claim **7** wherein the step of determining the lag includes altering the speed of one of the first and second gear pumps, and continually measuring at least one cross-sectional dimension of the extrudate to locate the change therein resultant from the pump speed alteration.

9. The process according to claim **2** further comprising varying the speeds of the pumps alternately from (1) stopped to (2) a fastest speed necessary to pump all of the material required to extrude the extrudate, and (3) back to stopped.

10. The process according to claim **1** further including forming inner and outer distinct coaxial layers of the first and the second kinds of materials respectively, and repetitively varying the relative speeds of the gear pumps to extrude layers that vary in thickness repetitively along the length of the extrudate.

11. The process according to claim **2** further comprising measuring the pressure differential across each of the pumps, and controlling each of the extruders to maintain a flow of material to the pump sufficient to keep the pump supplied with material without producing excessive pressure at an input side of the pump when pump speed is reduced.

12. The process according to claim **1** further including:

providing at least a third extruder having a third gear pump at an output end thereof, and

directing a further material from the third extruder through the third gear pump to the die.

13. The process according to claim **1** wherein the different materials differ in flexibility.

14. The process according to claim **1** wherein the different materials differ in color.

15. The process according to claim **1** wherein the different materials differ in opacity.

16. The process according to claim **1**, further comprising introducing a gas into a central opening in the extrudate and controlling the pressure of the gas to control a cross-sectional dimension of the extrudate.

17. The process according to claim **16** wherein the step of controlling the pressure of the gas to control a cross-sectional dimension comprises controlling an outside diameter of the extrudate, and the steps of directing materials comprise directing materials having differing dimension-affecting characteristics to the first and at least one further extruders.

18. The process according to claim **17** further comprising adjusting the speed of at least one of the gear pumps to further compensate for the differing characteristics and bring the inside and outside diameter to desired values at points of varying material content.

19. The process according to claim **17** wherein controlling the pressure includes introducing a sudden change in gas pressure into the extrudate, observing where the sudden change affects outside diameter to determine a lag and thereafter correcting the time at which compensatory gas pressure changes are made to correct for the lag.

20. The process according to claim **1** further including varying the cross-sectional dimension of the extrudate to produce a multiple material extrudate having predetermined changes in at least one cross sectional dimension.

21. The process according to claim **1** wherein the steps of providing first and at least one further extruder further comprises providing extruder screws for the first and further extruders having flights of a depth sufficient to prevent inertial rotation of the screws causing excessive pressure buildup between the screw and gear pump when the gear pump slows or stops.

22. The process according to claim **21** wherein providing extruder screws further includes providing extruder screws having a feed zone nearer an input end of the extruder and a metering zone nearer the output end of the extruder, the ratio of feed zone flight depth to metering zone flight depth being in the range of at least approximately 2 to 1.

23. A process of extruding an extrudate with different materials, the proportions of which vary along the length of the extrudate, including:

providing a first extruder having a first gear pump at an output end thereof,

providing at least one further extruder having a second gear pump at an output end thereof,

providing a die,

forming an extrudate having a first portion formed exclusively of material of one kind by directing material of the one kind from the first extruder through the first gear pump to the die,

forming in the extrudate a second portion formed exclusively of material of a second kind by directing material of the second kind from the at least one further extruder through the second gear pump to the die in the absence of mixing the two kinds of material,

varying the speed of at least one of the gear pumps to vary the relative output of the pumps and the content of the first and second kinds of materials in the extrudate.

24. A process of extruding an extrudate with different materials, the proportions of which vary along the length of the extrudate, including:

providing a first extruder having a first gear pump at an output end thereof,

providing at least one further extruder having a second gear pump at an output end thereof,

providing a die,

directing material of a first kind from the first extruder through the first gear pump to the die,

directing material of a second kind from the at least one further extruder through the second gear pump to the die, and

controlling the gear pumps to vary the speed of at least one of the gear pumps to vary the relative content of the first and second kinds of materials in the extrudate,

the steps of controlling the gear pumps including:

(i) momentarily changing the speed of one of the gear pumps to cause a measurable change in dimension of the extrudate,

(ii) observing the occurrence of the change in dimension at a location downstream of the die to determine an amount of lag between the gear pump speed change and the observed change in dimension, and

(iii) making gear pump speed adjustments in response to subsequently observed extrudate characteristics at a time determined to affect the extrudate at a desired location along its length as determined by the measured amount of lag.

25. The process according to claim **24** further comprising the steps of introducing a gas into an opening in the extrudate at a location proximate the die, changing the amount of introduced gas sufficiently to cause a measurable change in dimension of the extrudate, observing the occurrence of the change in dimension at a location downstream of the die to determine an amount of a second lag between the introduction of gas and the observed change in dimension, and making gas introduction adjustments in response to subsequently observed extrudate characteristics at a time determined to affect the extrudate at a desired location along its length as determined by the measured amount of second lag.

26. The process according to claim **24** including varying the speed of at least one other of the first and second gear pumps to vary the content of at least one further material in the extrudate.

27. The process according to claim **24**, further including adjusting the speed of at least one of the first and second gear pumps to control cross-sectional area in the extrudate.

28. The process according to claim **27** wherein adjusting the speed to control cross-sectional area includes adjusting the speed of one of the first and second gear pumps to compensate for differing dimension-affecting characteristics of the two kinds of materials such as affects a cross-sectional dimension of the extrudate.

29. The process according to claim **28** wherein adjusting the speed of one of the first and second gear pumps to compensate for differing dimension-affecting characteristics includes providing a compensatory incremental speed increase to the gear pump that pumps one of the different kinds of materials having a greater shrinkage as it cools.

30. The process according to claim **28** wherein adjusting the speed of one of the first and second gear pumps to compensate for differing dimension-affecting characteristics includes providing a compensatory incremental speed decrease to the gear pump that pumps one of the different kinds of material having a lower shrinkage as it cools.

31. The process according to claim **28** wherein the step of adjusting the speed comprises making a compensating speed change at a time that precedes by the determined lag the emergence from the die of that location on the extrudate where the compensatory change is to occur.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,725,814
DATED : March 10, 1998
INVENTOR(S) : Holton E. Harris

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Col. 11, line 36, "or" should read -- or 23 --.

Signed and Sealed this

First Day of September, 1998

Attest:

Bruce Lehman

BRUCE LEHMAN

Attesting Officer

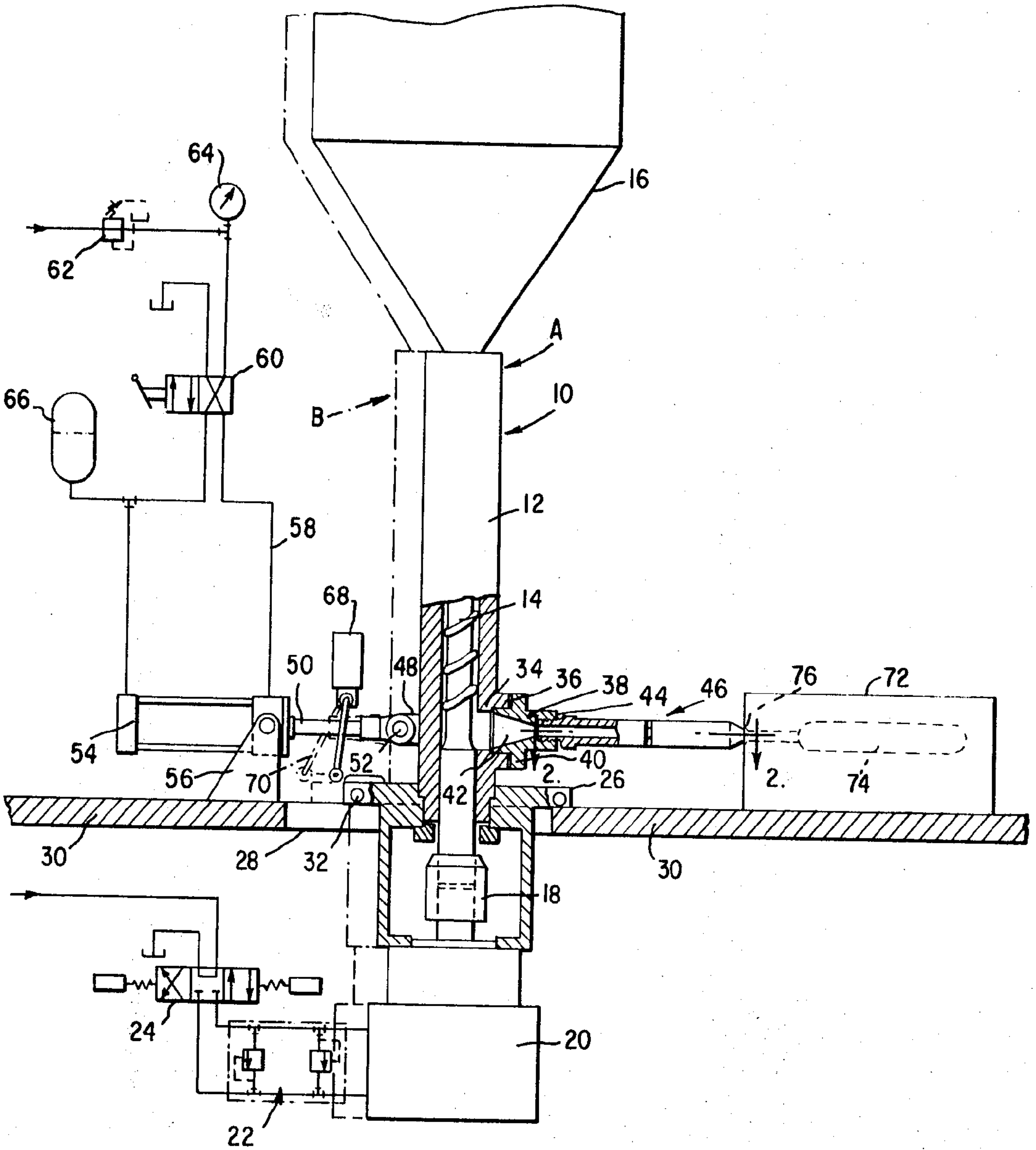
Commissioner of Patents and Trademarks

Oct. 12, 1971 J. A. JOHNSON **3,611,504**

NOZZLE SYSTEM AND INJECTION NOZZLE FOR INJECTION
BLOW MOLDING AND INJECTION MOLDING MACHINES

Filed Oct. 23, 1969 2 Sheets-Sheet 1

FIG. 1



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NOZZLE SYSTEM AND INJECTION NOZZLE FOR INJECTION BLOW MOLDING AND INJECTION MOLDING MACHINES

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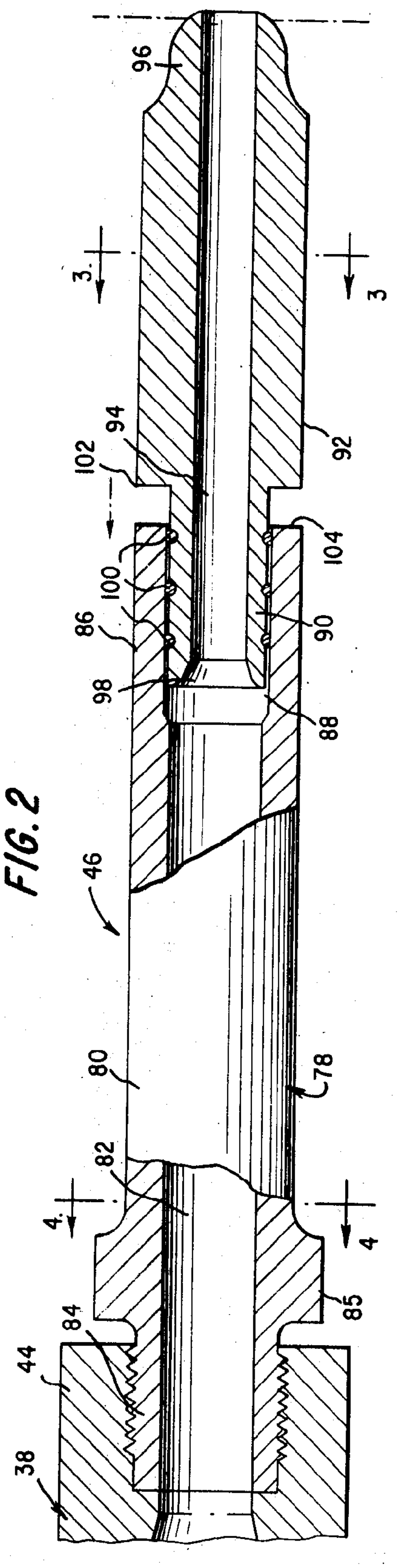

FIG. 2

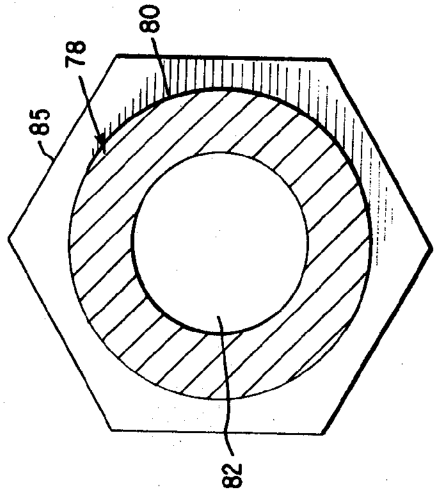

FIG. 4

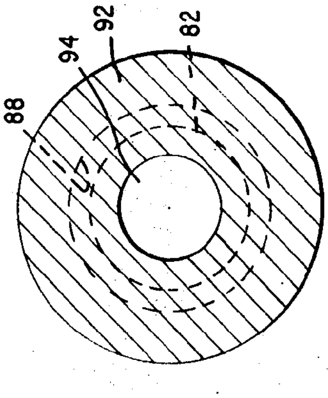

FIG. 3

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3,611,504
Patented Oct. 12, 1971

3,611,504

NOZZLE SYSTEM AND INJECTION NOZZLE FOR INJECTION BLOW MOLDING AND INJECTION MOLDING MACHINES

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Filed Oct. 23, 1969, Ser. No. 868,766
Int. Cl. B29f *1/03*
U.S. Cl. 18—30 CR **9 Claims**

ABSTRACT OF THE DISCLOSURE

An extruder screw mechanism for injecting plastic melt into a mold cavity is mounted for bodily movement relative to the mold and has a telescopic injection nozzle unit that is extended by the plastic material pressure in the mold cavity with which the tip of the nozzle unit is in sealing engagement so as to cause the screw mechanism to move back away from the mold against the holding pressure of a hydraulic cylinder. The movement of the mechanism actuates a limit switch that controls a solenoid valve to stop the screw and reverse its rotation for a timed interval, decompressing the plastic melt in the nozzle unit to prevent plastic melt drool when the cavity opens, and allowing the nozzle unit to return to its original shortened position.

BACKGROUND OF THE INVENTION

(1) Field of the invention

This invention generally appertains to new and novel improvements in a nozzle system and injection nozzles for injection molding and injection blow molding machines and more particularly relates to a new and novel means for the prevention of overfilling and overpressurization of a mold cavity by an injection molding apparatus and a novel method of accurately controlling the pressure of plastic melt injected by an extruder screw mechanism into a mold cavity.

(2) Description of the prior art

In the operation of injection and/or injection blow molding machines, it is customary to use a feed screw, which is operatively mounted within a heating cylinder, for the moving of plastic material to one end of the screw assembly where there is a discharge nozzle that conveys the plastic melt into the cavity of a mold. When the predetermined amount of the plastic material has been accumulated at the nozzle end of the screw assembly, the material is forced through the nozzle into the mold cavity by moving the screw through the heating cylinder under the actuation of hydraulic motor.

In any such machine, the danger always exists of overfilling and overpressurizing the mold cavity which causes the plastic material to spew or ooze out from the mold cavity and the tip of the nozzle resulting in defects in the molded articles and also hindering subsequent molding operations as a result of the plastic material becoming cool and hardened around the tip of the nozzle.

The prior art has been aware of this problem and has attempted to obviate the same by providing a valve arrangement for the discharge nozzle. One of the best exemplary disclosures of this manner of solving the problem is disclosed in the patent to Goodwin, No. 2,668,325 issued Feb. 9, 1954. In such patent, the nozzle has a valve that is carried by a plunger which is spring urged in the closed position. Pressure of the overfilling plastic material in the mold cavity urges the plunger upwardly in the nozzle and the head of the plunger contacts and actuates limit switches that effect, through suitable circuitry, stoppage and reverse rotation of the feed screw. When the feed screw is reversed, a loss of pressure takes place in the nozzle so as to permit the spring to act on the plunger and close the valve in its nozzle seat, whereby the flow of plastic material from the tip of the nozzle is shut off.

SUMMARY OF THE INVENTION

It is a primary object of the present invention to prevent overfilling and overpressurization of a mold cavity by an injection molding apparatus by means of an internally unobstructed and simple nozzle structure that is formed to function as an actuating means for moving the entire plastifier unit away from the mold into operating engagement with a control means for the feed screw.

Generally stated, the present invention provides a screw and heating cylinder plastifier unit that is slidably mounted on a base which fixedly supports a mold having a cavity provided with a mouth that is formed to sealingly receive the tip of a nozzle unit for the plastifier unit. A hydraulic holding cylinder acts on the plastifier unit to seat the nozzle tip in the mouth of the mold cavity. Under actuation of a hydraulic motor drive the feed screw is rotated within the heating cylinder to inject plastic material through the nozzle unit into the mold cavity. The nozzle unit is composed of an inject nozzle body defined by a cylindrically shaped steel bar having a bore formed axially therethrough for passage of plastic material from an output end of the heating cylinder to which one end of the bar is attached by a threaded cap. The other end of the inject nozzle body has a precision axial bore for the telescopingly sliding fit of an inject nozzle tip. The inject nozzle tip has a smaller axial bore than the inject nozzle body and the plastic melt in the nozzle passage acts upon the differential area of the nozzle body and the nozzle tip to force the two components axially apart. The force of the plastic melt, causing the two parts of the nozzle unit to separate, is resisted by the controlled hydraulic pressure in the holding cylinder, thus controlling the pressure of the plastic melt in the mold cavity.

The inject nozzle tip has a spherical radius at its output end which forms a seal with a spheroidal seat or mouth in the mold cavity. The nozzle tip is formed in the surface, which forms a sliding bearing with the nozzle body, with a plurality of axially spaced apart annular grooves that collect plastic melt which leaks from this connection so as to provide an additional lubricant for the sliding fit between the nozzle body and the nozzle tip and which also clean the plastic material from the inner surface of the nozzle body.

When the pressure of the plastic material in the mold cavity, acting on the differential area of the two piece, telescopic nozzle unit, exceeds the pressure of the holding cylinder, that is controlled by a hydraulic pressure reducing valve, the entire plastifier unit slides on the base away from the mold so as to permit the nozzle unit to extend. When the plastifier unit moves away from the mold, it actuates an electrical limit switch that through a solenoid valve stops the feed screw and reverses the rotation thereof for a timed interval, decompressing the plastic melt in the nozzle unit, thus preventing plastic melt drool when the mold cavity opens and allowing the nozzle unit to return to its original shortened position.

The plastic melt pressure can be varied by the adjustment of the pressure reducing valve having a display gauge which is calibrated in pounds per square inch of plastic melt pressure.

From the foregoing general explanation of the invention it can be appreciated that an important object of the present invention is to provide a simple but highly reliable and most efficient mechanical arrangement for preventing overfilling and overpressurization of a mold cavity by an injection molding apparatus and, commensurate therewith, to provide a novel method of accurately controlling the pressure of plastic melt injected by an extruder screw mechanism into a mold cavity.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevation, in a somewhat diagrammatic manner, of an injection molding machine embodying the present invention.

FIG. 2 is an enlarged longitudial sectional view of the nozzle assembly as taken substantially on line 2—2 of FIG. 1,

FIG. 3 is a transverse sectional view taken substantially on line 3—3 of FIG. 2.

FIG. 4 is a transverse sectional view taken substantially on line 4—4 of FIG. 2.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now more particularly to the accompanying drawings and initially to FIG. 1 for an understanding of the overall injection molding machine or apparatus, generally designated by the numeral **10**, it can be seen that the same includes a vertically disposed heating cylinder **12** within which a feed screw or worm **14** is operatively housed. A material hopper **16** is in communication with the upper end of the cylinder **12** and material from the hopper is conveyed down through the heating cylinder **12** by the feed screw **14** which is actuated through a drive coupling **18** by a hydraulic drive motor unit **20**. The hydraulic drive motor unit **20** is provided with a hydraulic control circuit including dual relief valves **22** and a solenoid operated 4-way valve **24**.

The lower end of the heating cylinder **12** is supported by a carriage **26** within which the drive coupling **18** is housed with the depending screw end portion within the carriage being in sealed relation with the lower end of the cylinder. The carriage **26** is supported in an opening **28** in a fixed base **30** and is movably mounted on the base by rollers **32** so that the entire plastifier unit, essentially composed of the heating cylinder **12** and the feed screw **14**, can move from the full line position A of FIG. 1 to the phantom line position B of FIG. 1.

The heating cylinder **12** is provided above the carriage **26** with a radial outlet **34** that has an external encircling shoulder **36**. A cap **38** is sealingly fitted in the outlet **34** and has a mounting flange **40** that is fixed to the shoulder **36**. The cap **38** has a frusto-conical bore **42** with the major end thereof being a diameter substantially equal to the diameter of the outlet **34** with which it is in adjoining communication. The minor end of the bore **42** communicates with an internally threaded collar **44** of the cap and the collar supports a telecopic nozzle unit or assembly **46** which will be more particularly described in regards to FIGS. 2–4.

The heating cylinder **12**, on its side point diametrically opposite to the nozzle unit **46**, is provided with a mounting ear arrangement **48** to which the outer end of a piston rod **50** is attached by a pivot pin **52** with the piston rod being in axial alignment with the nozzle unit **46**. The piston rod **50** is operatively carried by a hydraulic holding cylinder **54** that is fixedly supported in a horizontal position above the base **30** by a supporting bracket **56** which upstands from the base.

The hydraulic holding cylinder **54** has a hydraulic control circuit **58** that includes a manual 4-way valve **60**, a pressure reducing valve **62** with a gauge **64** and an accumulator **66**.

An electrical limit switch **68** is provided and has a swinging contact arm **70** that is vertically oriented in the path of the rearward movement of the carriage **26** so as to be struck by the carriage. The limit switch **68** controls the 4-way solenoid valve **24**.

The base **30** supports in any suitable fixedly located manner a mold **72** that has a cavity **74** which is provided with a spherical entrance mouth **76** that defines a seat for the outer end of the tip of the nozzle unit **46**, as will be described.

With reference more particularly to FIGS. 2–4, the nozzle unit **46** includes an inject nozzle body **78** that is a cylindrical shaped steel bar **80** having a longitudinal tubular bore **82** formed therethrough for the passage of the plastic material. The nozzle body has an externally threaded inner end **84** which is screwed into the collar **44** on the cylinder cap **38** so that the bore **82** is in perfect axial alignment and communication with the minor end of the bore **42** of the cap **38**. For the purpose of enabling the end **84** of the nozzle body to be screwed into the collar **44** the bar **80** is formed adjacent the end **84** with a multifaced shoulder **85** that can be engaged by a wrench or similar tool. The bore **82** at the end **84** is of substantially the same diameter as the minor end of the cap bore **42**.

The nozzle body **78** at its outer end portion **86** has a smooth counterbore **88** which is of slightly larger diameter than the bore **82** and which defines a precision bore for slidably receiving a tubular, coaxially reduced inner end portion **90** of a nozzle tip **92**, such inner end portion **90** constituting a sliding extension of the nozzle tip and cooperating with the bore **88** to provide the telescopic interfit between the nozzle body **78** and the nozzle tip **92**.

The nozzle tip **92** has an axial bore **94** that is of a smaller diameter than the bore **82** in the nozle body **78**. The bore **94** is of a constant diameter from the outer reduced spherical end **96** of the nozzle tip to a point spaced slightly inwardly from the end of the coaxially reduced sliding extension end portion **90**. At such point, the bore **94** is flared outwardly to provide a bell end **98** on the end portion **90** with the outwardly flared bell end **98** providing a smooth merging transition portion from the diameter of the bore **82** in the nozzle body **78** to the smaller diameter of the bore **94** in the nozzle tip **92** and also serving as a differential impact area between the nozzle body **78** and the companion telescopic nozzle tip **92**.

The plastic melt in the nozzle passage or bore **82** acts upon the differential area **98** between the nozzle body and the nozzle tip to force the two parts apart. The force of the plastic melt, which causes the two parts of the nozzle unit to separate, is resisted by the controlled hydraulic pressure in the hydraulic holding cylinder **54**, thus controlling the pressure of the plastic melt in the mold cavity **74**.

The inject nozzle tip **92** has a spherical radius at its output end **96** which forms a seal with the spherical seat **76** of the mold cavity **74**. The nozzle tip **92** has a number, for example three, of longitudinally spaced annular grooves **100** formed in the exterior surface of the sliding extension **90** that forms the sliding bearing with the nozzle body **78**. The grooves **100** collect plastic melt which leaks from this sliding connection forming an additional lubricant for the sliding fit and also cleaning the plastic material from the inner surface of the nozzle body. The nozzle body and the nozzle tip are of substantially the same outer diameter and at the inner end of the sliding extension **90** the nozzle tip has a shoulder **102** which is adapted to abut against the flat outer end **104** of the nozzle body in the original or shortened position of the telescopically arranged nozzle parts.

In operation, the manual 4-way valve **60** is actuated to cause the holding cylinder **54** to seat the spherical end **96** of the nozzle tip **92** in the seat **76** of the mold cavity **74** with the nozzle parts being in their normal shortened relation. The solenoid 4-way valve **24** is then energized to cause the hydraulic motor drive **20** to rotate the feed screw **14** so as to inject plastic material into the mold cavity.

When plastic material pressure in the mold cavity, acting on the differential area **98** of nozzle unit **46**, exceeds the pressure of the holding cylinder **54**, controlled by the hydraulic pressure reducing valve **62**, the entire plastifier unit rolls back on the cylinder carriage **26**, allowing the two piece nozzle unit **46** to extend. As the plastifier unit moves back, the carriage strikes the arm **70** of the limit switch **68** to actuate the limit switch that controls the 4-way solenoid valve **24** so as to stop the rotation of the feed screw **14** and reverse the rotation thereof for a timed interval. This decompresses the plastic melt in the nozzle unit or assembly **46**, thus preventing plastic melt drool when the mold cavity opens and allowing the nozzle unit to return to its original shortened position.

The plastic melt pressure can be varied by adjustment of the pressure reducing valve **62** with the values displayed on the gauge **64** that is calibrated in pounds per square inch of melt pressure.

It can thus be seen that a simple but most dependable and very sturdy means is provided for preventing overfilling and overpressurization of the mold cavity with the plastifier unit being mounted for bodily movement to actuate a limit switch that controls the operation of the feed screw of the plastifier unit and the plastifier unit being urged rearwardly away from the mold cavity and into contact with the limit switch by the telescopic nozzle unit or assembly in its reaction to the plastic material pressure in the mold cavity against the pressure of the holding cylinder which is controlled by the adjustable pressure reducing valve.

I claim:

1. A molding machine comprising an extruder mechanism including an injection nozzle and nozzle tip for injecting plastic melt into a fixedly located mold cavity, means mounting the extruder mechanism for bodily movement toward and away from the fixedly located mold cavity, a hydraulic holding cylinder for holding the extruder mechanism against movement away from the mold cavity, means for controlling the operation of the extruder mechanism, said controlling means being disposed in the path of movement of the extruder mechanism away from the mold cavity, and means responsive to plastic melt pressure in the mold cavity in opposition to the holding pressure of the holding cylinder for moving the extruder mechanism except the nozzle tip away from the mold cavity and causing it to engage and actuate the controlling means whereby further injection of the plastic melt into the mold cavity is discontinued.

2. A molding machine comprising an extruder mechanism for injecting plastic melt into a fixedly located mold cavity, means mounting the extruder mechanism for bodily movement toward and away from the fixedly located mold cavity, a hydraulic holding cylinder for holding the extruder mechanism against movement away from the mold cavity, means for controlling the operation of the extruder mechanism, said controlling means being disposed in the path of movement of the extruder mechanism away from the mold cavity, and means responsive to plastic melt pressure in the mold cavity in opposition to the holding pressure of the holding cylinder for moving the extruder mechanism away from the mold cavity and causing it to engage and actuate the controlling means whereby further injection of the plastic melt into the mold cavity is discontinued, said last named means includes a telescopic nozzle unit communicatingly connecting the extruder mechanism with the mold cavity for the passage of the plastic melt from the extruder mechanism into the mold cavity.

3. The invention of claim **2** wherein said telescopic nozzle unit includes a nozzle body fixedly carried by the extruder mechanism and a nozzle tip, said nozzle body and said nozzle tip having telescopically arranged adjoining ends and a differential area at said ends upon which the plastic melt passing within the nozzle unit acts to cause the nozzle body and the nozzle tip to separate.

4. The invention of claim **3** wherein said nozzle tip terminates in outer output end having a spherical radius adapted to sealingly mate with an entrance mouth of the mold cavity.

5. The invention of claim **3** wherein said nozzle tip has a coaxially reduced inner end portion, said nozzle body having an outer end provided with a precision bore slidingly receiving the inner end portion and said inner end portion having an exterior surface formed with a series of longitudinally spaced annular grooves that are adapted to collect plastic melt leaking from such connection and forming a lubricant for the sliding bearing fit between the inner end portion and the bore.

6. The invention of claim **2** wherein a base is provided upon which the mold cavity is fixedly located, said extruder mechanism being supported by a carriage rollingly mounted on the base and constituting the mounting means for the extruder mechanism.

7. The invention of claim **2** wherein means is provided for adjusting the holding pressure of the holding cylinder so as to vary the plastic melt pressure operable to effect the movement of the extruder mechanism.

8. A molding machine comprising an extruder mechanism for injecting plastic melt into a fixedly located mold cavity, means mounting the extruder mechanism for bodily movement toward and away from the fixedly located mold cavity, a hydraulic holding cylinder for holding the extruder mechanism against movement away from the mold cavity, means for controlling the operation of the extruder mechanism, said controlling means being disposed in the path of movement of the extruder mechanism away from the mold cavity, and means responsive to plastic melt pressure in the mold cavity in opposition to the holding pressure of the holding cylinder for moving the extruder mechanism away from the mold cavity and causing it to engage and actuate the controlling means whereby further injection of the plastic melt into the mold cavity is discontinued, said controlling means includes a limit switch, said extruder mechanism including a heating cylinder and a screw rotatably mounted in the heating cylinder, a hydraulic motor drive for the screw and having a hydraulic circuit including a solenoid operated valve and said limit switch controlling the valve so as to control the rotary movements of the screw.

9. The invention of claim **2** wherein an adjustable pressure reducing valve with a setting gauge is provided for the holding cylinder so as to adjust the holding pressure of the holding cylinder and thereby vary the plastic melt pressure operable to effect the movement of the extruder mechanism.

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U.S. Cl. X.R.

18—2 HA, 30 NR